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ONTARIO WATER RESOURCES COMMISSION

REPORT

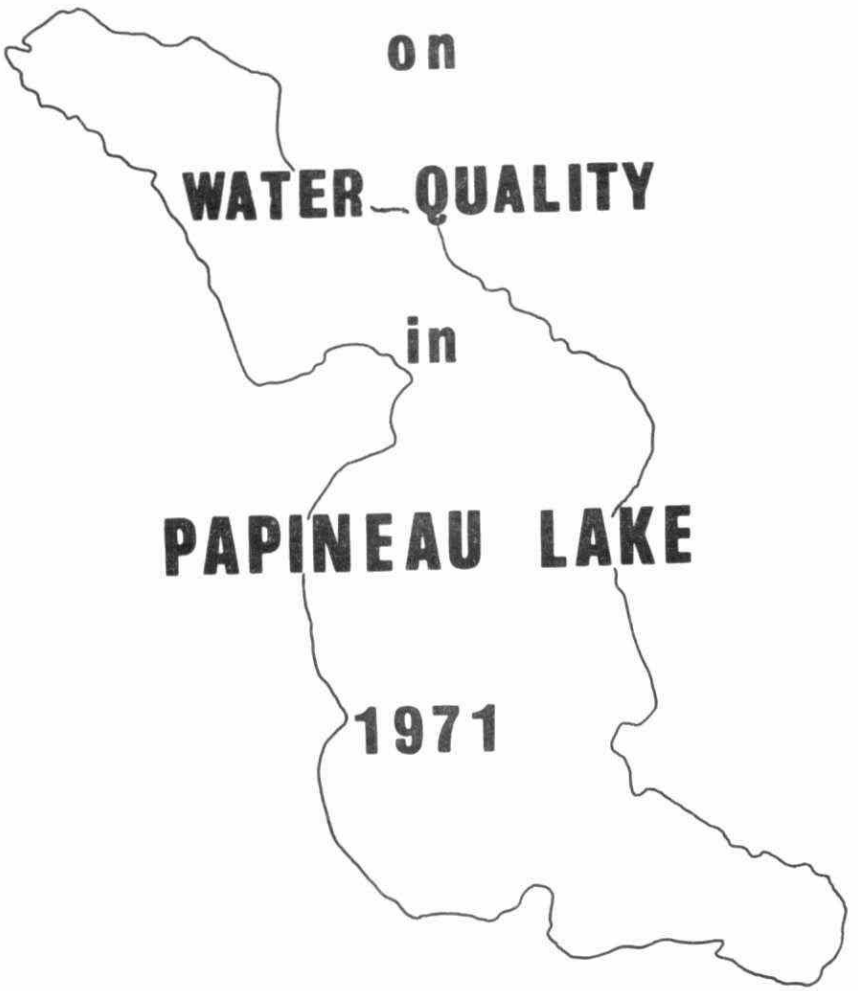
on

WATER QUALITY

in

PAPINEAU LAKE

1971



RECREATIONAL LAKES PROGRAM

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1971

Report on water quality in
Papineau lake : 1971.

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THE

ONTARIO WATER RESOURCES COMMISSION

REPORT

ON WATER QUALITY

IN

PAPINEAU LAKE

1971

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SUMMARY

A study to evaluate the status of water quality in Papineau Lake was carried out during the summer of 1971.

Papineau Lake lies within the Precambrian Shield. The area is characterized by rolling hills, poor local drainage and shallow overburden covering Precambrian bedrock. The shoreline slopes are covered with a thin layer of a variety of top soils ranging from humus to sandy overburden. Rock outcrop dominates most of the shoreline. Both the nature of the soils and the topography around the lake can be considered unsuitable for standard subsurface septic tank disposal bed systems.

The lake was surveyed for five days on three occasions for chemical, biological and bacteriological parameters.

Thermal stratification was observed during the July and September surveys. A metalimnetic oxygen increase was present during the July survey. There was no appreciable oxygen depletion observed in the bottom waters at any time.

The concentrations of chlorophyll a were well below nuisance levels reflecting the unproductive nature of the lake. Indicators of early mesotrophy were evident from diatom analysis performed on surface sediments.

The chemical water quality was very uniform over the stations sampled and was characteristic of soft water Precambrian lakes unaffected by waste inputs. The use of detergents containing phosphates is unnecessary in such soft water and should be avoided by area residents.

During the June survey the lake was well within the OWRC bacteriological criteria for recreational use except for stations 24 and 25 which exceeded the criteria for Fecal Streptococcus (FS).

The Fecal Coliform (FC) counts also indicated a small pollution input along the south-east shore in the vicinity of these stations.

In July the lake was well below the criteria except for Station 1 at the north-west end which exceeded the criteria for FS. This station was probably affected by runoff from a creek.

The lake was bacteriologically homogeneous during September with low numbers of bacteria having overall geometric means of 2 Total Coliforms (TC) per 100 ml, 1 FC/100 ml and 1 FS/100 ml which were well below the criteria.

In order to maintain the existing quality of the water, every effort should be made to ensure that direct flow or leachate from domestic waste disposal systems or other potential sources of pollution do not gain access to the lake.

INTRODUCTION

Maintenance of good water quality in recreational lakes in the Province of Ontario is of vital concern to the Ontario Water Resources Commission, The Ontario Department of the Environment and other governmental agencies involved in tourism and the control and management of shoreline development of cottages and resorts. In 1970 an interdepartmental program was established to survey a number of recreational lakes in order to detect and correct sources of water pollution and ensure that our lakes would be well managed to protect water quality. The Ontario Department of Health, whose jurisdiction in this program was transferred to the Department of the Environment in December 1971, would carry out on-shore inspection and correction of faulty private waste disposal systems, whereas the Ontario Water Resources Commission would evaluate the existing water quality of the respective lakes.

Recreational lakes are subjected to two major types of water quality impairment; bacteriological contamination and excessive growths of algae and aquatic weeds (eutrophication). The two problems may result from a common source of wastes but the consequences of each are quite different. Bacteriological contamination by raw or inadequately treated sewage poses an immediate public health hazard if the water is used for bathing. In order for this to occur, raw wastes or septic tank effluents must gain entry to the lake although it may not be obvious upon visual inspection of the site. It must be noted that no surface water is considered safe for human consumption without prior treatment including disinfection. The algae and weed problems which have come into prominence in recent years are caused by plant nutrients being added to the lake. Excessive algae and weed growths impair aesthetic values and recreational use of a lake but seldom pose a health hazard. There are nutrient sources other than sewage wastes which do not create serious bacterial hazards but do support nuisance plant growths such as agricultural fertilizer losses and normal nutrient runoff from forest and field.

In line with its responsibility of evaluating the status of water quality in recreational lakes, the Ontario Water Resources Commission undertook a study on Papineau Lake in the summer of 1971. Three surveys were conducted in Papineau Lake; a spring survey from June 4 to 8, a mid-summer survey from July 9 to 13 and a fall survey from September 25 to 29 inclusive. The scope of the work included the assessment of the bacteriological, physical, chemical and biological conditions of the lake with stress being placed on the bacteriological and nutrient enrichment problems.

Sampling surveys were conducted on an intensive basis (sampling each day for a minimum of five days) which is mandatory for an accurate assessment of bacteriological conditions.

In addition to the results obtained from these studies, information from other governmental agencies has been incorporated in this report which is the Ontario Water Resources Commission's contribution to the Interdepartmental Task Force Report which will deal with the overall cottage pollution program in Ontario.

AREA DESCRIPTION

Geography and Topography

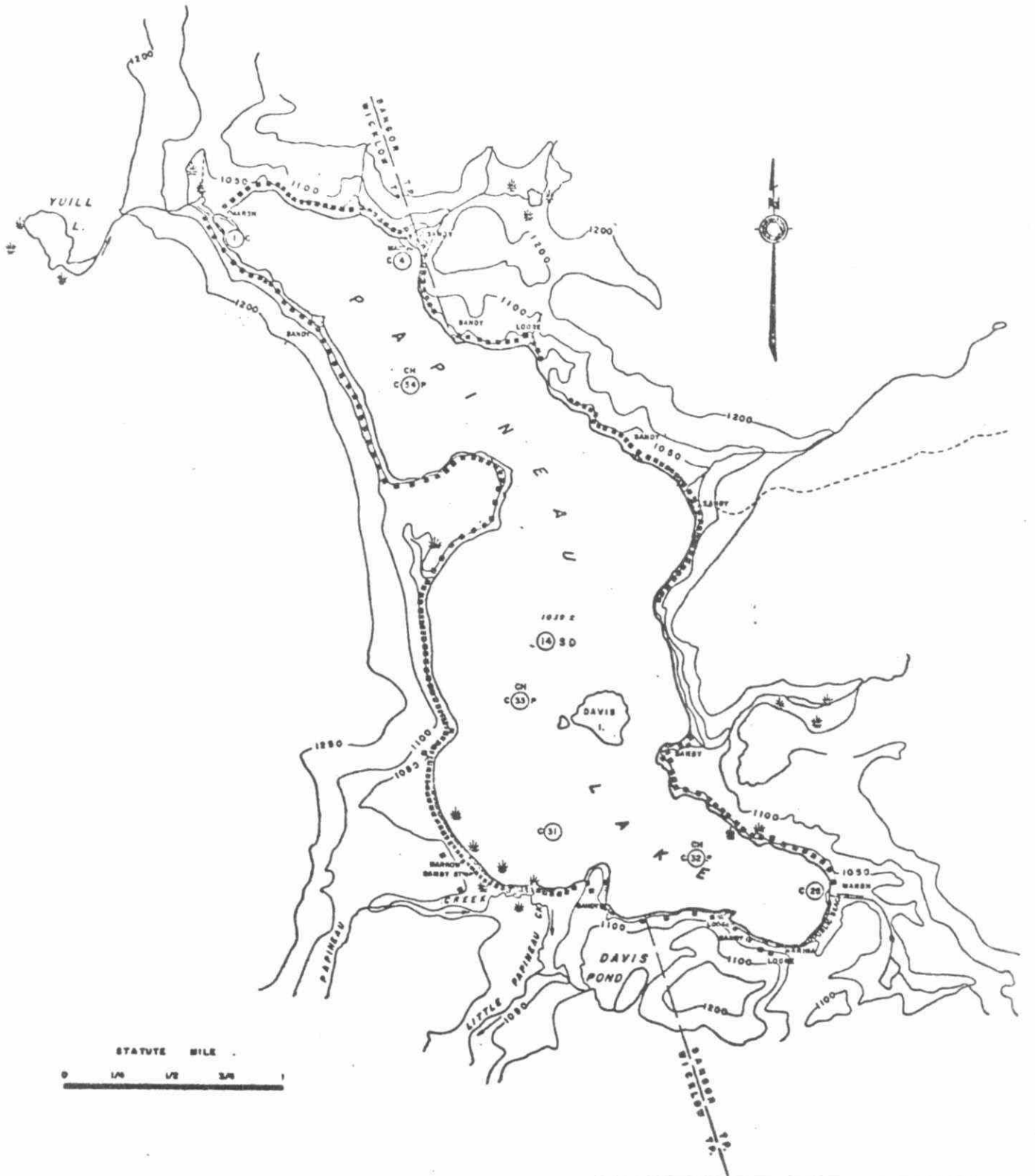
Papineau Lake (Figure 1) is located in the Township of Bangor and Wicklow, County of Hastings, approximately 20 miles north of Bancroft. It has a surface area of 1980 acres and a maximum depth of 200 feet. The 13.6 mile shoreline is dominated by steep slopes rising more than 200 feet above the lake level within a distance of 0.25 miles. The lake basin can be described as a deep "V" with the lake bottom sloping almost as sharply as the surrounding terrain.

The watershed, which includes a number of small lakes and watercourses consists of 11,500 acres of land, lying within the Precambrain Shield and is characterized by forested rolling hills. The greatest portion of land surrounding Papineau Lake belongs to the Rockland soil series. This series is comprised of 50 to 90 per cent granite and granite gneiss thinly covered with a mixture of humus and sand overburden, with small deposits of deeper soil materials in the crevices. The south-east tip of the lake and the area between the two branches of Papineau Creek belong to the Bancroft Series which consists of a sandy loam with a weak Podzol development. This type of development is made up of infertile soil found typically in forests and consists of a thin ash-coloured layer overlaying a brown acidic humus. Deposits such as these were usually laid down by glacial streams. In general, the area surrounding the lake has a thin layer of soil cover ranging from a few inches to pockets of six feet in depth in a terrain dominated by rock outcrop. In most areas the overburden is less than the minimum of five feet required by the Department of the Environment for installation of a septic tank system.

Climate Range

The area has a mean temperature range of 12 to 14^{o}F in January and 66 to 70^{o}F in July. The annual precipitation is in the range of 28 to 40 inches including 80 inches of snow. According to meteorological reports the area enjoys about 270 days of no measurable precipitation. The summer climate is conducive to most recreational activities and the winter with its abundance of snow early in the season provides for participation in most winter sports.

FIGURE 1



LEGEND

■ — COTTAGES & DWELLINGS

1200 CONTOUR LINES

CH C 34 P — SAMPLING STATION

C - CHEMICAL CH - CHLOROPHYLL

P - PROFILE SD - SEDIMENT DIATOM

ONTARIO WATER RESOURCES COMMISSION

RECREATIONAL LAKES PROGRAM

PAPINEAU LAKE

1971 WATER QUALITY SURVEY

SCALE:- AS SHOWN	
DRAWN BY: A. J. H.	DATE: DECEMBER 1971
CHECKED BY: A.M	DRAWING NO: 72-8-DE.8

Water Movement

Papineau Lake lies in the Ottawa River Terminal Drainage Basin and is fed by three tributaries; Little Papineau Creek, Poplar Creek and McCormick Creek. Little Papineau Creek flows intermittently into the lake over a natural sand bar located in its junction with the lake. However, during the spring high water level in the lake, the flow in the junction between the creek and the lake is reversed providing the lake with its only period of overflow to the York River (Figure 1).

Shoreline Development

The shoreline of Papineau Lake is generally well developed with the exception of a small stretch of the east shore near its south end. There are approximately 250 summer cottages (half of which are quite closely spaced), three privately owned resorts and two public bathing beaches (Figure 1).

Water Usage

Most of the cottagers use the lake as their source of doemestic water supply. It is very actively used for recreational purposes such as boating, fishing, water skiing and swimming as well as for winter sports. According to information available from the Department of Lands and Forests the lake offers a sport fishery of lake trout, brook trout, smallmouth bass and northern pike. Some of the dominant coarse fish in the lake are white sucker, rock bass, bullhead and lake herring. The records indicate that the quality of trout angling has decreased considerably since 1960.

At the present time there are no direct discharges of raw or treated wastes into Papineau Lake from municipal or individual sewage treatment facilities. The area residents are provided with three municipal solid waste disposal sites located within 0.5 miles of the lake. Two disposal sites, one on lot 2 concession 9, Township of Wicklow and the other on lot 3 concession 4, Township of Bangor appear to be satisfactory and are not posing any pollution hazards to the lake. The third site is located on lot 4 concession 9, Township of Bangor and is scheduled to be abandoned in the spring of 1972 and replaced with a site located in the same township on lot 1, concession 10.

FIELD AND LABORATORY METHODS

Physical, Chemical and Biological Field Methods

Physical, chemical and biological samples were collected at three near-shore stations; 1, 4 and 25, and at three mid-lake stations; 32, 33 and 34. The near-shore stations were adjacent to the major inlets and outlets.

At the mid-lake stations dissolved oxygen and temperature profiles were determined daily using a combination dissolved oxygen-telethermometer unit. Additionally, samples for pH, alkalinity and free CO_2 were secured 1 meter (m) below the surface and from 1m above the bottom. pH measurements were obtained with a portable pH meter, and total alkalinity and free CO_2 were determined titrimetrically. Daily chlorophyll samples were collected in a 32-ounce bottle at each mid-lake station, utilizing a composite sampler lowered through the euphotic zone (2X Secchi disc) and immediately preserved with 10-15 drops of 2% $MgCO_3$.

At least once during the year a 32-ounce sample for hardness, alkalinity, chloride, total phosphorus, total Kjeldahl nitrogen, iron and conductivity was collected at the above stations. The mid-lake samples were taken through the euphotic zone and the near shore samples from 1m using a Kemmerer sampler. In addition, at stations 33 and 34 one sample was collected 1m from the bottom with a Kemmerer sampler and submitted for total phosphorus, total Kjeldahl nitrogen and iron analyses.

Three sediment cores for diatom frustule examination were collected during the late autumn at station 14. From the surface of each sediment core, three sub-samples were removed for laboratory enumeration to species.

Physical, Chemical and Biological Laboratory Methods

All analyses were carried out using routine OWRC methods based on Standard Methods 13th Edition.

Iron was measured after the sample had been digested with acid to dissolve all forms of iron present.

Kjeldahl nitrogen and total phosphorus were determined after the sample was digested with acid and an oxidizing agent to destroy organic matter.

For chlorophyll determinations, 1 liter samples were filtered through a 1.2 μ membrane filter which was then extracted with 90% acetone for 24 hr. Absorbance of the extract was determined at wavelengths 600 to 750 mμ using a Unicam SP1800 ultra violet spectrophotometer. The concentrations of chlorophyll a were calculated using the equation given by Richards and Thompson (1955).

Bacteriological Field and Laboratory Methods

Five day intensive bacteriological surveys were completed on Papineau lake during June, July and September. Each day 31 stations were sampled at a depth of 1m below the surface using sterile, autoclavable polycarbonate 250 ml bottles. Additional samples were collected at stations 5, 10, 14, 22, 31 (Figures 5, 6, & 7) 1m above the bottom using a modified "piggy-back" sampler and sterile 237 ml evacuated rubber air syringes. All samples were stored on ice and delivered to the mobile laboratory within two to six hours and analyzed for total coliforms, fecal coliforms and fecal streptococci using the membrance filtration technique (MF) (Standard Methods 13th Edition) except that m-Endo Agar Les (Difco) was used for total coliform and MacConkey membrane broth (Oxoid) was used for total coliform determinations. The total coliforms (TC), fecal coliforms (FC) and fecal streptococci (FS) were used as "indicators" of fecal pollution. These "indicators" are the normal flora of the large intestine, and are present in large numbers in the feces of man and animals. When water is polluted with fecal material, there is a potential danger that pathogens or disease causing microorganisms may also be present.

The coliform group is defined, according to Standard Methods 13th Edition, as "all of the aerobic and facultative anaerobic, gram-negative, non-sporeforming rod-shaped bacteria which ferment lactose with gas formation within 48 hours at 35°C" and, or "all organisms which produce a colony with a golden green metallic sheen within 24 hours of incubation" using the MF technique. This definition includes, in addition to the intestinal forms of the Escherichia coli group, closely related bacteria of the genera Citrobacter and Enterobacter. The Enterobacter - Citrobacter groups are common in soil, but are also recovered in feces in small numbers and their presence in water may indicate soil runoff or, more important, less recent fecal pollution since these organisms tend to survive longer in water than do members of the Escherichia group, and even to multiply when suitable environmental conditions exist. A more specific test for coliforms of intestinal origin is the fecal coliform test, with incubation of the organisms at 44.5°C. Though by no means completely selective for Escherichia coli, this test has proved useful as an indicator of recent fecal pollution.

Fecal streptococci (or enterococci) are also valuable indicators of recent fecal pollution. These organisms are large, ovoid, gram-positive bacteria, occurring in chains. They are normal inhabitants of the large intestine of man and animals, and they generally do not multiply outside the body. In water polluted with fecal material, fecal streptococci are ususally found along with coliform bacteria, but in smaller numbers, although in some waters they may be found alone. Their presence, along with coliforms, indicates that at least a portion of the coliforms in the sample are of fecal origin. All the bacteriological data collected in these surveys has been summarized by statistical methods to form a concise outline of the bacterial concentrations.

Statistical Methods

The results from all the analyses were organized as replicates representing the stations during the survey period. All data were transformed to logarithms (base 10) and all further analyses were done

using these transformed data. A geometric mean (the antilogarithm of the average of the logarithm) was calculated on each station for each parameter. The validity of the analysis of variance program (ANOVA CRE; Burger 1972) was based on the assumption that the variances of all the stations were similar (Bartlett's test of Homogeneity) and that the data were normally distributed. Both these assumptions were checked on Papineau Lake. The Bartlett's test was found to be non-significant and the data followed a normal distribution, so the analysis of variance (F-test; Sokal, 1969) was calculated on all the stations. If the F was significant, then the multiple-t test was used to help determine the stations which should be deleted from the overall group to yield a homogeneous group of stations. The withdrawn stations were regrouped with respect to geographic proximity and similar means. The calculations an all groups were repeated using the analysis of variance program until each discrete group was homogeneous. The homogeneous groups that were geographically isolated were compared by means of the Student-t test (using the log GM and S.E.) which indicated the statistical difference between these groups. The Student-t test was also used to compare the grouped bacteriological data from the three surveys to each other.

DISCUSSION OF RESULTS

Temperature and Dissolved Oxygen

During the June survey, a temperature difference of 8.0°C existed between the surface (12.5°C) and bottom (4.5°) waters at station 33 (Figure 2). Similar temperature differences were recorded at stations 32 and 34 (Table 1a). Dissolved oxygen saturations changed slightly with depth at all stations (Table 1b).

During July, a well-defined thermocline characterized by a temperature change of 8°C between 5 and 8m was apparent at station 32 (Figure 3a). There was a distinct metalimnetic maximum of oxygen detected at station 32 on July 13. A number of authors including Eberly (1959, 1963 and 1964) Wetzel (1966) and Baker et al. (1969) indicated such dissolved oxygen distribution curves were characteristic of mesotrophic lakes. However, such oxygen curves are common in relatively small Precambrian lakes and are usually accompanied by a shallow thermocline, a Secchi disc depth exceeding 5m, and nutrient-chlorophyll production regimes characteristic of oligotrophic lakes as was the case in Papineau Lake.

In September the thermocline was somewhat deeper than in July, being located between the 9 and 12m depths. There was no observed severe hypolimnetic oxygen decrease, although bottom water saturations were slightly lower in September than during the July survey. This deficit was probably related to decomposition of the current years' production of algae, following settling through the metalimnion.

The average surface temperatures of 12.3, 21.2 and 18.2°C during the three surveys respectively, were in keeping with the expected seasonal changes.

pH, Total Alkalinity and Free Carbon Dioxide

In Papineau Lake, surface pH values were near neutral, being consistent with soft-water Precambrian Lakes. The pH was generally higher in the surface waters than in the deeper strata. For example, at station 32 on July 9, values at 1 and 16m were 6.8 and 6.3, respectively.

FIGURE 2

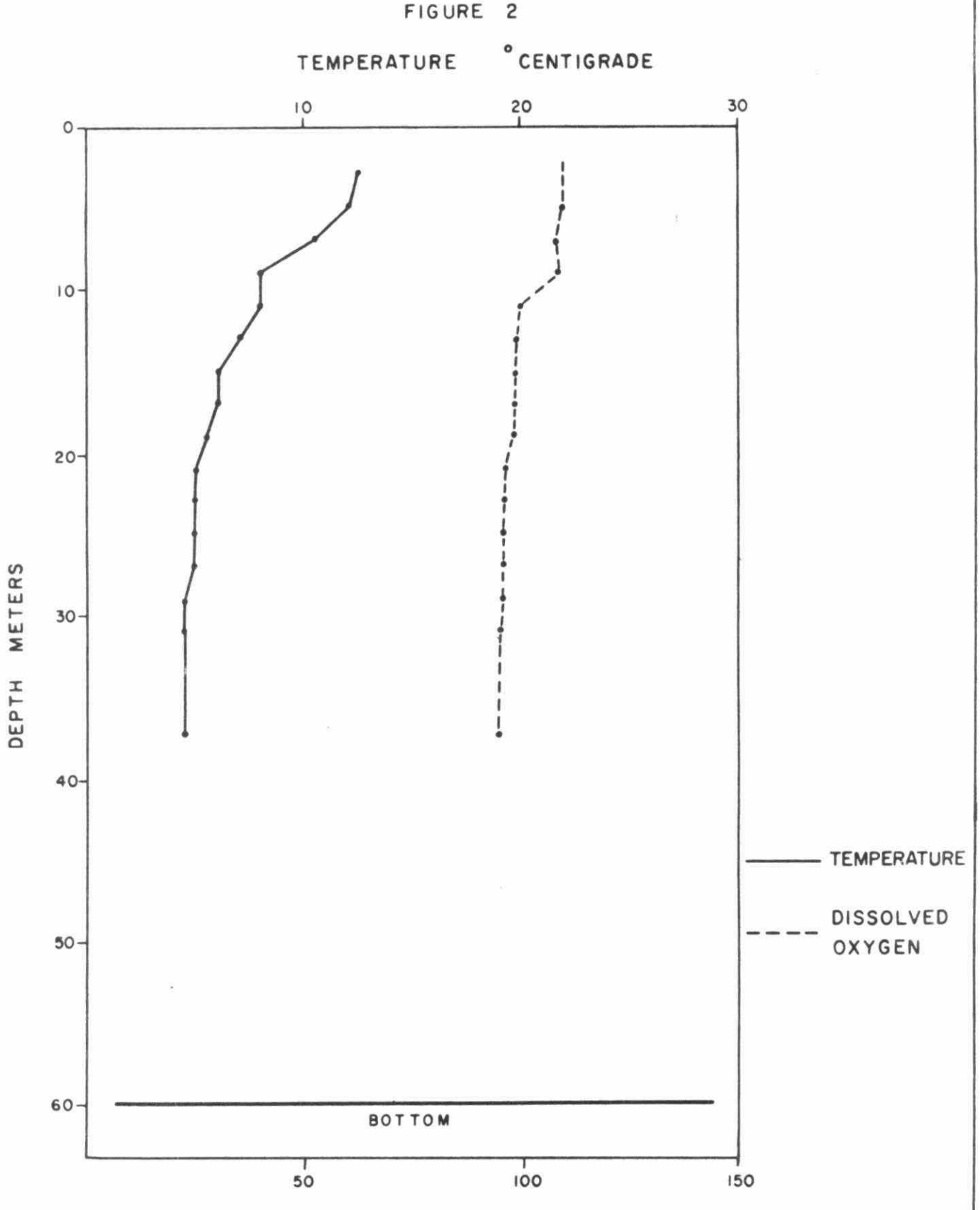


Figure 2 Temperature and dissolved oxygen profiles in Papineau Lake, station #33, June 5, 1971.

FIGURE 3a

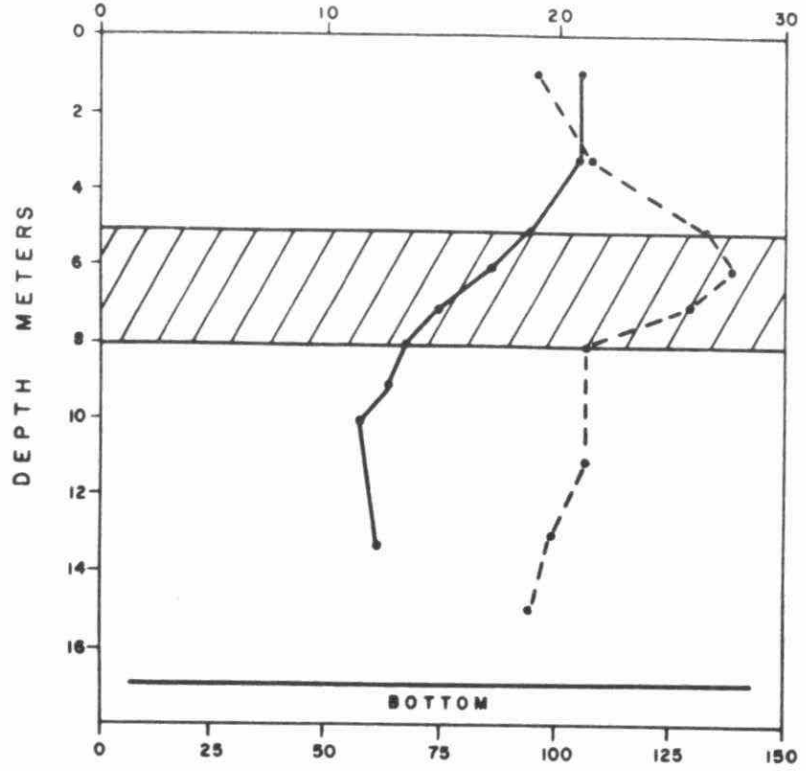


FIGURE 3b

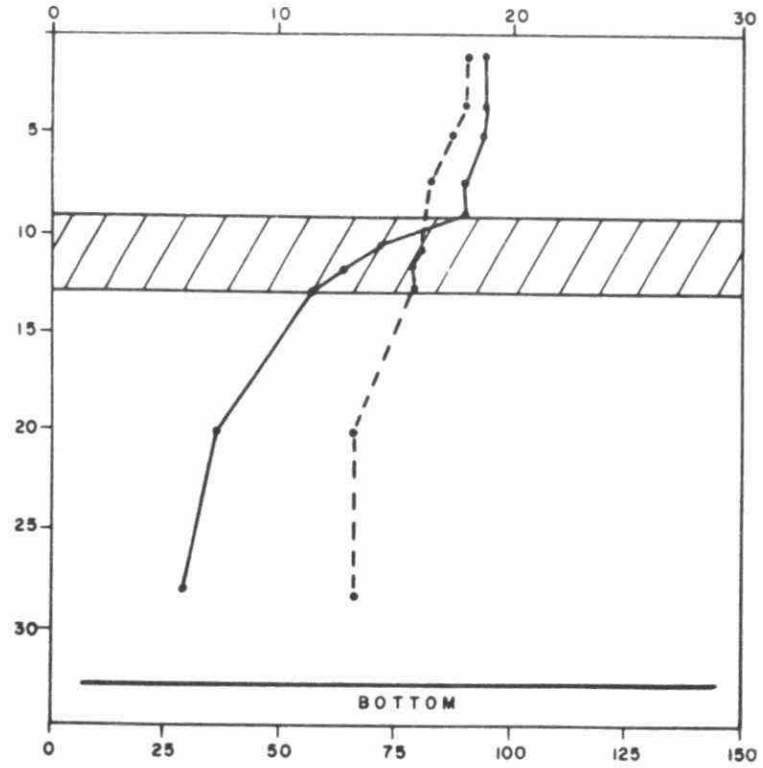


FIGURE 3

Temperature ——

Dissolved Oxygen -----

Temperature and dissolved oxygen profiles in Papineau Lake, (a) station #32 for July 13, 1971 and (b) station #34 for September 25, 1971. The shaded areas approximate the position of the thermocline.

Free carbon dioxide and total alkalinity concentrations were usually higher in the hypolimnion than in the warmer surface waters. On July 5, free carbon dioxide concentrations at 1 and 16m were 3.4 and 5.8 mg/l, respectively. Corresponding total alkalinity values were 10.6 and 10.8 mg/l. Reduced pH values in the hypolimnion are due to the accumulation of carbon dioxide derived from organic decomposition while the increased alkalinity is related to the release of bicarbonate from sediments by bacterial and chemical action in conjunction with calcium, magnesium, iron, manganese and ammonia.

Conductivity, Chloride, Hardness and Iron

Conductivity (48 to 52 µmhos/cm^3), chloride (2 to 3 mg/l), hardness (17 to 18 mg/l) and iron (0.05 to 0.10 mg/l) were all within the expected analytical range thus indicating uniform water quality over the stations sampled. These values are typical of soft water lakes and are consistent with each other confirming that no unusual mineral characteristics were present. Soaps will be effective in such soft water and the use of detergents containing phosphorus is unnecessary.

Kjeldahl Nitrogen and Total Phosphorus

Surface concentrations of Kjeldahl nitrogen (0.21 to 0.36 mg/l) and total phosphorus (0.006 to 0.012 mg/l) were very low in July and would not be expected to support nuisance levels of algae.

In September, Kjeldahl nitrogen concentrations were even lower (0.09 to 0.17 mg/l) while total phosphorus was slightly higher than in July (0.009 to 0.020 mg/l).

Hypolimnetic samples taken at stations 32 and 33 on July 13 had very low nitrogen 0.19 and 0.21 mg/l and total phosphorus 0.004 and 0.009 mg/l indicating that recycling of nitrogen and phosphorus from the sediments was not occurring.

The weight ratios of Kjeldahl nitrogen to total phosphorus averaged 41 which is characteristic of natural water unaffected by waste inputs (Edmondson 1970).

Chlorophyll a

Chlorophyll a concentrations were very low during the three sampling periods ranging from 0.6 to 5.2, 0.3 to 1.3 and from 0.4 to 0.9 µg/l for the June, July and September surveys, respectively (Table 2). These values reflect extremely low algal populations.

Water clarity, which is one of the more important parameters used in defining water quality, can be measured using a Secchi disc. Figure 4 presents a chlorophyll a - Secchi disc relationship for a number of surface waters and clarifies the "trophic status" of Papineau Lake in relation to numerous other well known recreational lakes in the Province (see Brown 1972 for derivation of chlorophyll a - Secchi disc relationships). With respect to Figure 4, Papineau Lake with a mean Secchi disc value of 6.0 m is positioned in close proximity to values observed for the oligotrophic lakes, Superior and Huron and is well-removed from Gravenhurst Bay, Riley Lake (District of Muskoka) and the Western Basin of Lake Erie, three extremely enriched bodies of water

Sediment Diatom Analysis

The developmental history of a lake may be examined by studying the distribution and succession of diatoms in lake sediments. Using a ratio of diatom groups, Araphidinae to Centrales (A/C) in lake sediments Stockner (1971) has developed a technique which classifies the trophic status in a number of soft water lakes in north-west Ontario. The author developed the following broad trophic distinctions for lakes:

Type	Ratio
Oligotrophic	0-1.0
Mesotrophic	1.0-2.0
Eutrophic	>2.0

The frustules are well preserved under most limnological conditions and due to their specific gravity, sink to the bottom and remain in the sediments. Therefore, a sediment sample extracted from the upper one centimeter of the core contains diatoms representative of the recent trophic status of a lake.

FIGURE 4

CHLOROPHYLL a - SECCHI DISC RELATIONSHIP

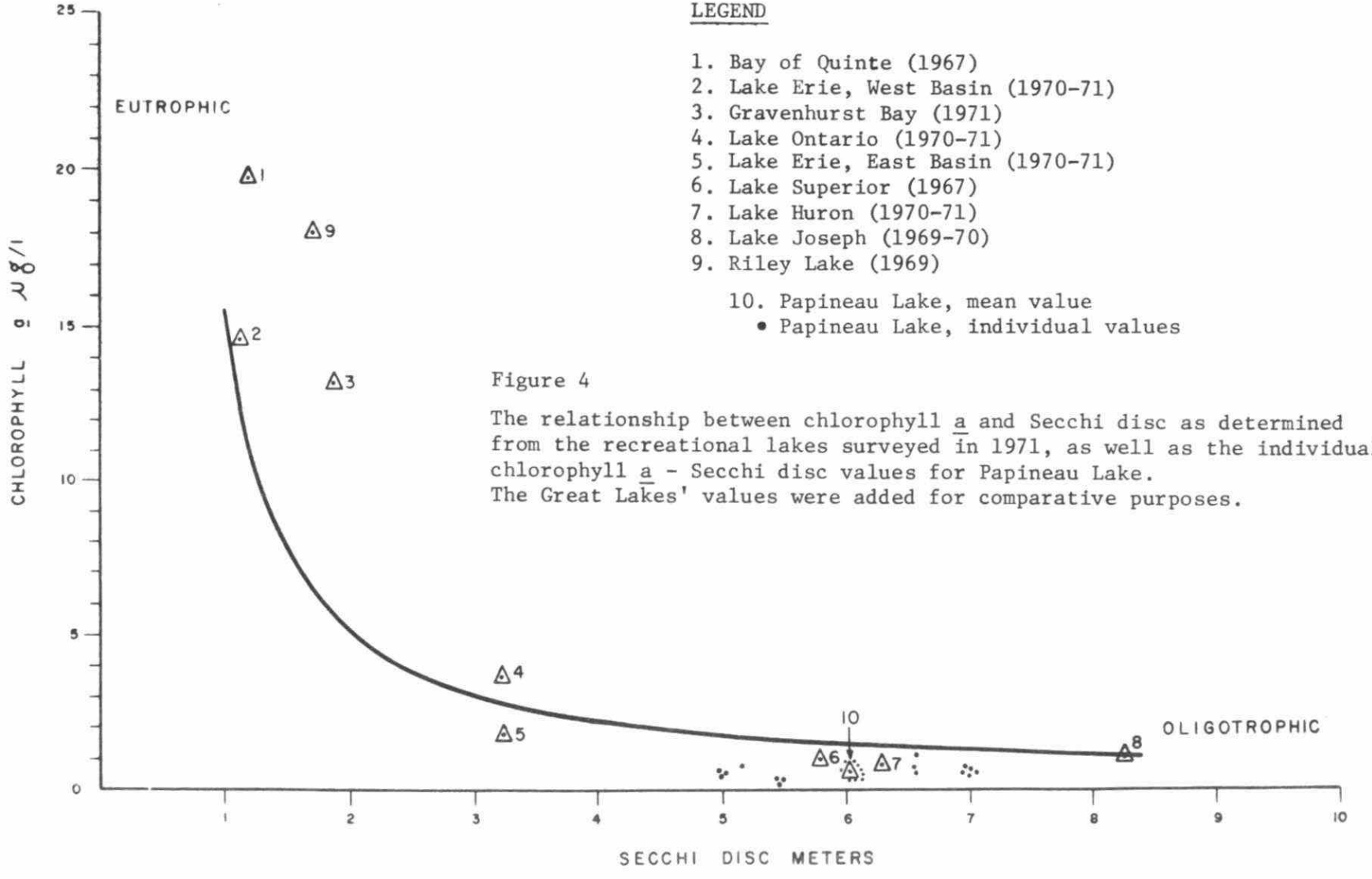


Figure 4

The relationship between chlorophyll a and Secchi disc as determined from the recreational lakes surveyed in 1971, as well as the individual chlorophyll a - Secchi disc values for Papineau Lake.
The Great Lakes' values were added for comparative purposes.

To classify Papineau Lake with respect to its trophic status, triplicate analysis on three sediment cores collected from station 14 were examined. Mean A/C ratios of 1.1, 0.9 and 0.9 (Table 3) indicate that the lake contains planktonic diatom populations which are characteristic of oligotrophic to early mesotrophic lakes.

Bacteriology

The summaries of the analysis of variance grouping of stations are presented in Tables 4, 5, & 6. Summaries of the tests of significance (Student-t test) between variance groups are presented in Table 7. Table 8 shows the summaries of Student-t tests between geographically distinct analyses of variance groupings. The maps (Figures 5, 6 & 7) show the location of the stations on the lake and the geographic relationship of the analysis of variance groupings.

Papineau Lake, with few exceptions, was well within the OWRC criteria for total body contact recreational use during the three surveys (OWRC 1970).

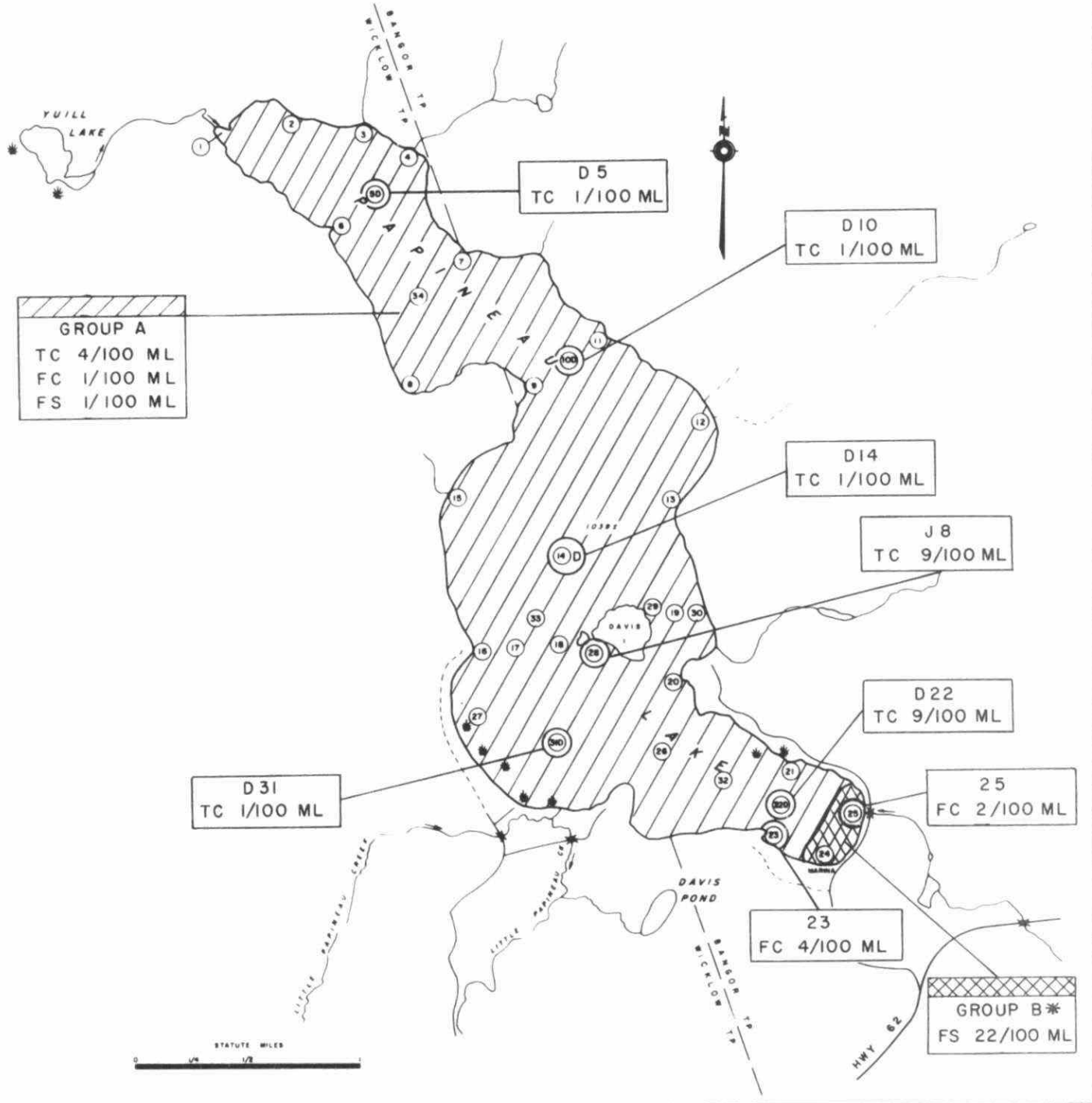
In June, the lake had an overall TC level of 4/100 ml with the exception of stations D5, D10, D14, D31 and 28 which were geographically discrete, with TC levels uniformly lower than the rest of the lake and station D22 which had a TC count of 9/100 ml (Table 7a). The FC concentrations over most of the lake were very low (1 FC/100 ml) but stations 23 and 25 located at the southeast end of the lake, were somewhat higher at 4 and 2 FC/100 ml, respectively (Table 5). Similarly, FS levels were 1/100 ml except for Group B at the south-east end of the lake which had significantly higher levels of FS (22/100 ml; Table 6) and exceeded the OWRC criteria for recreational use.

The above mentioned observations indicate a slight but definite pollution source at the south-east corner of the lake, which, according to the FC/FS ratio (Geldreich 1968) was likely due to runoff in the area of stations 24 and 25. This was supported by data from the meteorological station at Purdy which showed 0.18 inches of rain fell on June 2, 0.32 inches fell on June 7 and 0.22 inches on June 8. Similar rainfall data collected at Combermere. The FC count indicated a very small but

PAPINEAU LAKE

FIGURE 5

JUNE SURVEY JUNE 4 - 8, 1971



LEGEND

GROUP OR STN
TC 6 M/100ML
FS 6 M/100ML
FS - 6 M/100 ML

(14) — BACTERIOLOGICAL STATION

D — DEPTH STATION

* — EXCEED OWRC CRITERIA FOR RECREATIONAL USE

ONTARIO WATER RESOURCES COMMISSION

RECREATIONAL LAKES PROGRAM

PAPINEAU LAKE

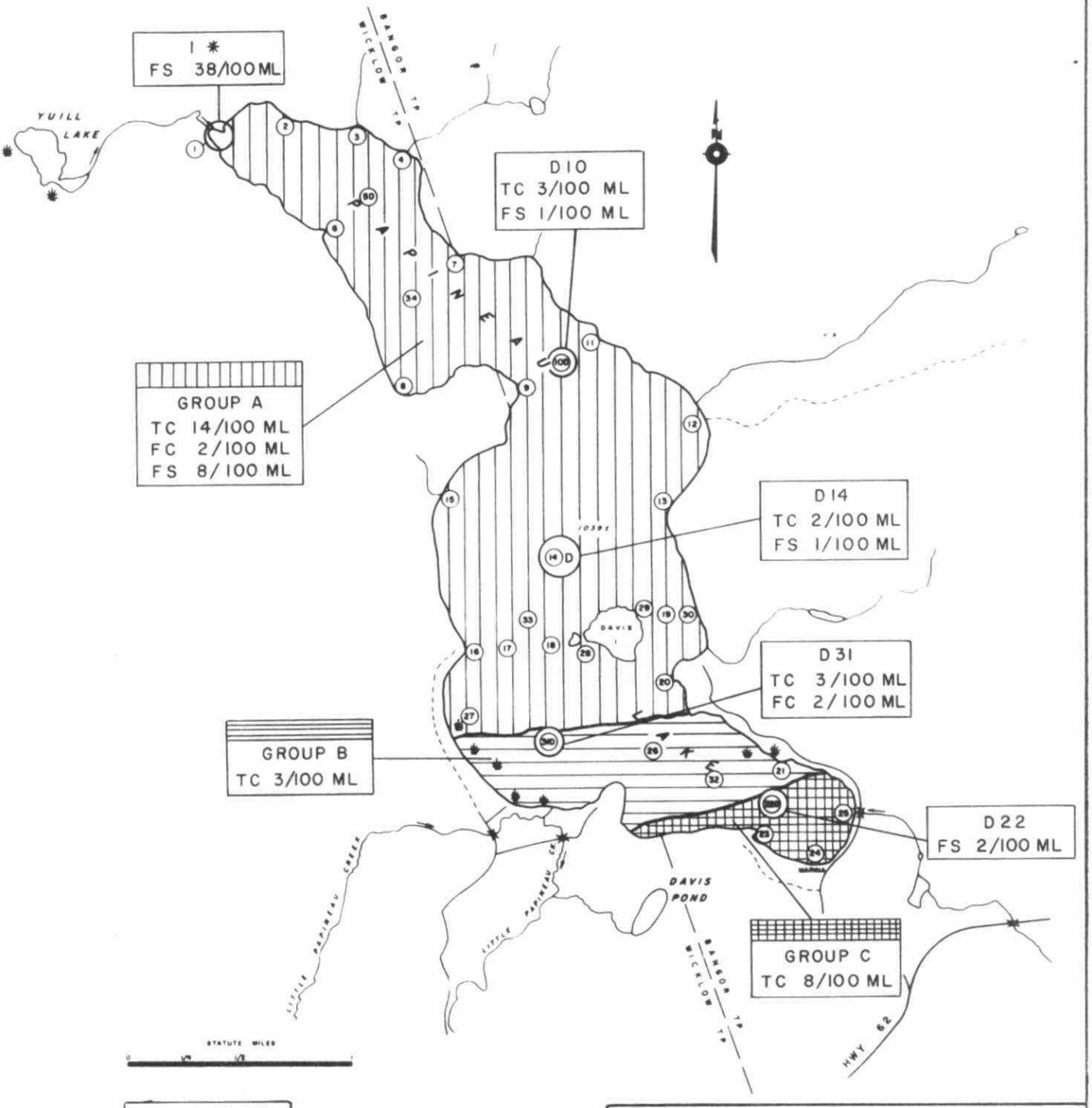
1971 WATER QUALITY SURVEY

SCALE:- AS SHOWN	
DRAWN BY: A.J.H.	DATE: DECEMBER 1971
CHECKED BY: A.M.	DRAWING NO. 72-8-DE.A

PAPINEAU LAKE

FIGURE 6

JULY SURVEY JULY 9 - 18, 1971



LEGEND

GROUP OR STN
TC 6M/100 ML
FC 6M/100 ML
FS 6M/100ML

(14) — BACTERIOLOGICAL STATION

D — DEPTH STATION

* — EXCEED OWRC CRITERIA FOR RECREATIONAL USE

ONTARIO WATER RESOURCES COMMISSION

RECREATIONAL LAKES PROGRAM

PAPINEAU LAKE

1971 WATER QUALITY SURVEY

SCALE:- AS SHOWN	
DRAWN BY: A.J.H.	DATE: DECEMBER 1971
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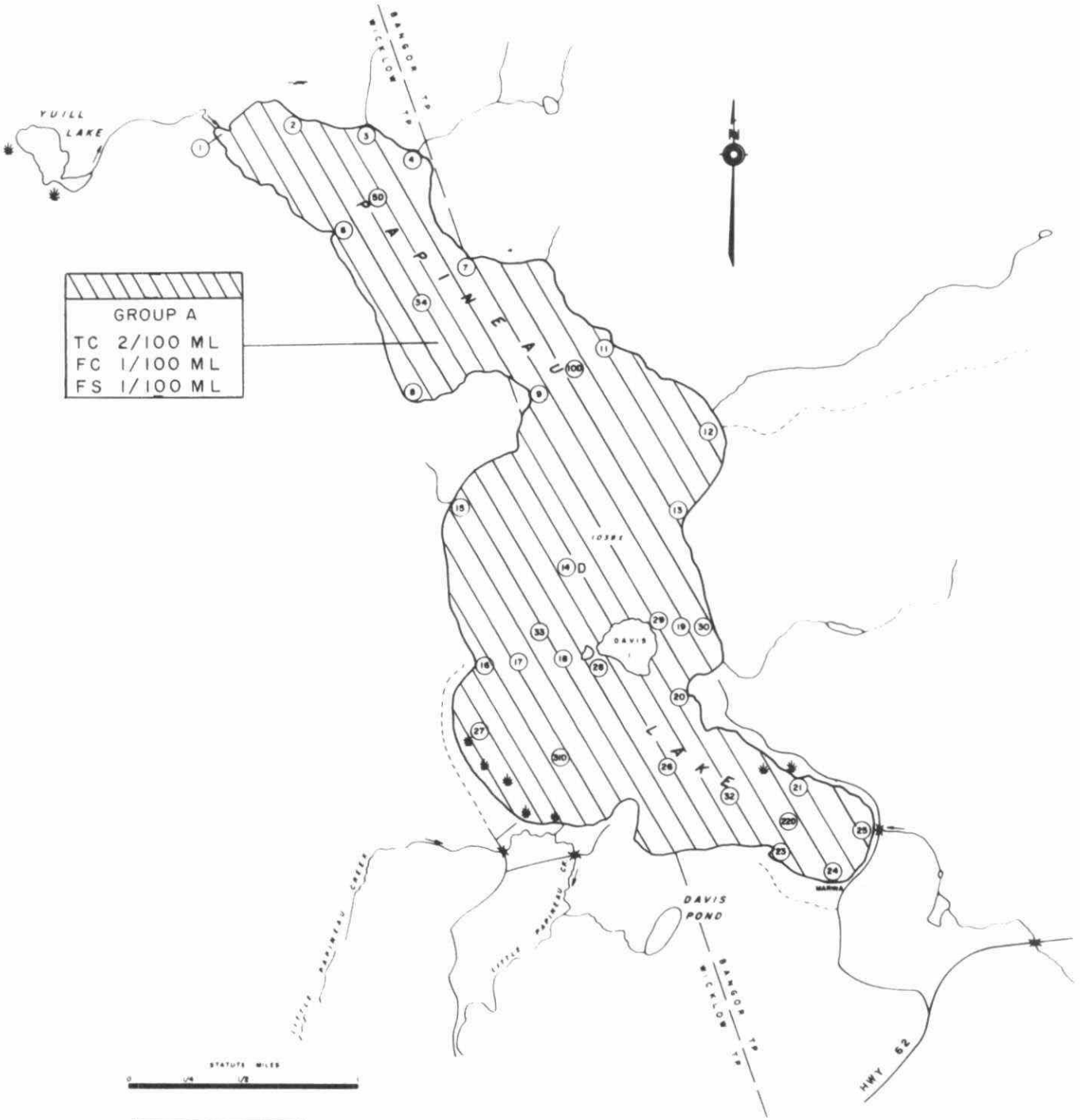
PAPINEAU LAKE

FIGURE 7

SEPTEMBER SURVEY SEPT. 25 - 29, 1971



LEGEND

GROUP OR STN
TC 6M/100ML
FC 6M/100ML
FS 6M/100ML

(14) — BACTERIOLOGICAL STATION

D — DEPTH STATION

ONTARIO WATER RESOURCES COMMISSION

RECREATIONAL LAKES PROGRAM

PAPINEAU LAKE

1971 WATER QUALITY SURVEY

SCALE:- AS SHOWN	
DRAWN BY: A.J.H.	DATE: DECEMBER 1971
CHECKED BY: A.M.	DRAWING NO. 72-8-DE A

statistically significant pollution input at station 23 near cottages and a resort. However, this trend was not apparent in the July survey despite the fact that more than twice as much rain fell.

In the July survey the TC and FS counts showed an increase in numbers while the FC counts increased to a lesser extent (Table 8). All stations, in the July survey, except Groups B and C at the south end of the lake, and stations D10 and D14, had statistically similar TC counts of 14/100 ml. The exceptions had lower TC levels (Table 4). The FC concentrations were homogeneous throughout the lake at 2 FC/100 ml, and the FS concentrations were 8/100 ml except for the depth stations which were lower (Table 6). Station 1, which was significantly higher at 38 FS/100 ml, exceeded the OWRC criteria for recreational use and indicated a source of pollution. The Purdy meteorological station recorded 1.05 inches of rain on July 5 and 0.24 inches on July 8. This rainfall and the FC/FS ratio imply that the FS counts were due to runoff, probably collected in the creek and carried to the lake at station 1.

The entire lake was homogeneous with respect to all three parameters in September, with overall geometric means of 2 TC/100 ml, 1 FC/100 ml and 1 FS/100 ml. In the interval between the July and September surveys there was a decrease in TC, FC and FS levels (Table 8).

Generally, Papineau Lake in September had lower TC counts than in June, and the FC and FS counts remained very low, indicating that after the summer recreational use, the lake had reverted back to its original, bacteriological condition observed in the spring.

TABLE 1

Temperature ranges (degrees centigrade) and dissolved oxygen ranges (per cent saturation) for Papineau Lake during the summer of 1971.

a) Temperature ranges:

	STATION 32	STATION 33	STATION 34
JUNE SURVEY			
Epilimnion	6.0 - 13.5	4.5 - 12.5	5.0 - 12.5
Metalimnion	NO	THERMOCLINE	ESTABLISHED
Hypolimnion	---	---	---
JULY SURVEY			
Epilimnion	19.0 - 22.0	18.0 - 22.0	18.0 - 22.0
Metalimnion	12.0 - 20.0	12.0 - 18.0	12.0 - 17.0
Hypolimnion	10.0 - 12.0	10.0 - 12.0	9.0 - 14.0
SEPTEMBER SURVEY			
Epilimnion	17.8 - 18.9	17.8 - 18.9	17.9 - 18.5
	11.8 - 17.8	12.9 - 18.0	11.2 - 18.0
	9.0 - 13.0	6.0 - 13.0	6.0 - 13.5

b) Dissolved Oxygen ranges:

JUNE SURVEY			
Epilimnion	96 - 114	92 - 112	90 - 114
Metalimnion	NO	THERMOCLINE	ESTABLISHED
Hypolimnion	---	---	---
JULY SURVEY			
Epilimnion	106 - 138	108 - 138	112 - 138
Metalimnion	104 - 136	118 - 136	116 - 131
Hypolimnion	96 - 116	102 - 126	105 - 119
SEPTEMBER SURVEY			
Epilimnion	88 - 96	86 - 94	86 - 94
Metalimnion	64 - 89	75 - 89	72 - 88
Hypolimnion	36 - 73	56 - 82	40 - 72

TABLE 2

Chlorophyll a and Secchi disc values for Papineau Lake during 1971

		STATION 32		STATION 33		STATION 34	
		CHLOR. a	S.D.	CHLOR. a	S.D.	CHLOR. a	S.D.
June	5	1.5 µg/l	---	2.3 µg/l	---	2.3 µg/l	---
June	5	3.7	---	3.6	---	5.2	---
June	6	1.1	---	1.2	---	0.9	---
June	7	0.9	---	1.5	---	0.6	---
June	8	0.9	---	0.9	---	0.9	---
July	9	0.3	5.5m	0.3	5.5m	0.3	5.5m
July	10	0.6	6.5	0.8	6.0	0.9	7.0
July	11	1.3	6.0	1.3	6.5	0.6	6.5
July	13	0.6	5.0	0.6	5.0	0.6	6.0
Sept.	25	0.6	6.1	0.5	6.0	0.5	7.0
Sept.	26	0.6	6.0	0.6	6.0	0.6	5.0
Sept.	27	0.9	5.2	0.6	7.0	0.6	7.0
Sept.	28	0.4	7.0	0.5	6.0	0.5	6.0
Sept.	29	0.6	6.0	0.6	6.0	0.5	6.0

CHLOR. a = Chlorophyll a
S.D. = Secchi Disc
µg/l = Microgram/liter
m = Meters

TABLE 3

The Araphidinae/Centrales ratio of the surface sediments sample collected from Papineau Lake, Station 14 during the autumn of 1971. Three analyses on three separate cores were completed.

	CORE								
	A1	A2	A3	B1	B2	B3	C1	C2	C3
A/C Ratio	1.2	0.9	1.2	0.9	0.7	1.0	0.9	1.0	0.8
Mean A/C Ratio		1.1			0.9			0.9	

EXPLANATION OF TERMS IN BACTERIOLOGICAL TABLES

F - the calculated analysis of variance statistic on F ratio.

df - degrees of freedom of the F ratio for "between group" and "within group" variation.

F(5%) - the F ratio from a statistics table (Rohlf 1969). If the calculated F is greater than the F(5%), a significant difference (SD) occurred between the groups in the analysis. If the F is less than F(5%), no significant difference (NSD) occurred.

log GM - the logarithm (base 10) of the geometric mean.

S.E. - the standard error of the log GM where

$$S.E. = \frac{s}{\sqrt{n}}$$ and s = standard deviation

N - the number of values in the mean.

GM - the geometric mean of the bacterial level.

t - the calculated test of significance or student t-test used to compare stations, groups and a survey.

If t for the number of degrees of freedom shown is greater than the critical t value, a significant difference (SD) occurs.

SD refers to a significant difference at the .05 level but no significant difference at the .01 level.

SD* refers to a significant difference at the .01 level but no significant difference at the .001 level.

SD** refers to a significant difference at the .001 level.

TABLE 4

Summary of the Analysis of Variance Grouping of Stations

PARAMETER: Total Coliform (TC)/100 ml.

Survey	June 4 - 8, 1971	July 9 - 13, 1971	Sept. 25 - 29, 1971
Group	All Stations	All Stations	All Stations
F	1.956	2.470	0.414
df	35, 140	35, 131	25, 123
F(.05)	1.519	1.524	1.529
	SD	SD	NSD
Group	A All Stations except D5, D10, D14, D22, 28, D31	A All Stations except 21-26, 31, D31, D10 D14, D22	A All Stations
F	1.035	1.409	0.414
df	29, 117	24, 89	25, 123
F(.05)	1.572	1.645	1.529
	NSD	NSD	NSD
Log GM	0.6428	1.1438	0.3316
SE	0.0453	0.0484	0.0395
N	147	114	159
GM	4	14	2
Group or Station	Station D5	Group B Stations 21,26,21,D31	
F	-	0.372	-
df	-	3, 15	-
F(.05)	-	3.292	-
	-	NSD	-
Log GM	0.0000	0.4407	-
SE	0.0000	0.1140	-
N	5	19	-
GM	1	3	-

TABLE 4 - Continued

Survey	June	July	September
Group or Station	Station D10	Group C Stations 22-25	
F	-	0.785	-
df	-	3, 15	-
F(.05)	-	3.292	-
	-	NSD	-
Log GM	0.1505	0.9187	-
SE	0.1505	0.1100	-
N	4	19	-
GM	1	8	-
Station	D14	D10	
Log GM	0.0000	0.4408	-
SE	0.0000	0.2423	-
N	5	5	-
GM	1	3	-
Station	D22	D14	
Log GM	0.9771	0.3612	-
SE	0.3180	0.2919	-
N	5	5	-
GM	9	2	-
Station	28	D22	
Log GM	0.1806	0.5419	-
SE	0.1806	0.1997	-
N	5	5	-
GM	2	4	-
Station	D31		
Log GM	0.0000	-	-
SE	0.0000	-	-
N	5	-	-
GM	1	-	-

TABLE 5 - Summary of the Analysis of Variance Grouping of Stations
Parameter: Fecal Coliform (FC)/100 ml.

Survey	June 4 - 8, 1971	July 9 - 13, 1971	Sept. 25 - 29, 1971
Group	All Stations	All Stations	All Stations
F	1.531	1,220	0.797
df	35, 143	35, 142	35, 124
F(.05)	1.517	1.518	1.528
	SD	NSD	NSD
Group	A All Stations Except Stations 23 and 25	A All Stations	A All Stations
F	0.805	1.220	0.797
df	33, 135	35,142	35, 124
F(.05)	1.533	1.518	1.528
	NSD	NSD	NSD
Log GM	0.0422	0.3012	0.0237
SE	0.0157	0.0341	0.0077
N	169	178	160
GM	1	2	1
Station	23		
Log GM	0.6123	-	-
SE	0.2791	-	-
N	5	-	-
GM	4	-	-
Station	25		
Log GM	0.3612	-	-
SE	0.2408	-	-
N	5	-	-
GM	2	-	-

TABLE 6 - Summary of the Analysis of Variance Grouping of Station Parameter: Fecal Streptococcus (Enterococcus) (FS)/100 ml.

Survey	June 4 - 8, 1971	July 9 - 13, 1971	Sept. 25 - 29, 1971
Group	All Stations	All Stations	All Stations
F	3,543	4.479	1.458
df	35, 141	35, 144	35, 124
F(.05)	1.518	1.517	1.528
	SD	SD	NSD
Group	A All Stations Except 24 and 25	A All Stations Except 1, D5, D10, D14, D22, D31	A All Stations
F	0.791	1.290	1.458
df	33, 135	29, 120	35, 124
F(.05)	1.533	1.570	1.528
	NSD	NSD	NSD
Log GM	0.1259	0.8945	0.0776
SE	0.0274	0.0322	0.0200
N	169	150	160
GM	1	8	1
Group or Station	Group B Station 24&25	Station 1	
t	2.445	-	-
df	6	-	-
t(.05)	3.179	-	-
	NSD	-	-
Log GM	1.3491	1.5815	-
SE	0.2260	0.2167	-
N	8	5	-
GM	22	38	-

TABLE 6 - Continued

Survey	June	July	September
Station		D5	
Log GM	-	0.0602	-
SE	-	0.0602	-
N	-	5	-
GM	-	1	-
Station		D10	
Log GM	-	0.0602	-
SE	-	0.0602	-
N	-	5	-
GM	-	1	-
Station		D14	
Log GM	-	0.0000	-
SE	-	0.0000	-
N	-	5	-
GM	-	1	-
Station		D22	
Log GM	-	0.3010	-
SE	-	0.0952	-
N	-	5	-
GM	-	2	-
Station		D31	
Log GM	-	0.1806	-
SE	-	0.1204	-
N	-	5	-
GM	-	2	-

TABLE 7a - Summary of t-test between geographically distinct analysis of variance groupings within the June survey for total coliform (TC)/100 ml.

Station	D5	D10	D14	28
D10	t = 1.138 df = 8 t(.05) = 2.306 NSD			
D14	t = 0.000 df = 8 t(.05) = 2.306 NSD	t = 0.999 df = 7 t(.05) = 2.365 NSD		
28	t = 0.99 df = 8 t(.05) = 2.306 NSD	t = 2.152 df = 7 t(.05) = 2.365 NSD	t = 0.999 df = 8 t(.05) = 2.306 NSD	
D31	t = 0.000 df = 8 t(.05) = 2.306 NSD	t = 0.999 df = 7 t(.05) = 2.365 NSD	t = 0.000 df = 8 t(.05) = 2.306 NSD	t = 0.999 df = 8 t(.05) = 2.306 NSD

TABLE 7b - Summary of t-test between geographically distinct analysis of variance groupings within the July survey for total coliform (TC)/100 ml.

Group or Station	Group B	Group C	Station D14
Group C	t = 3.017 df = 36 t(.05) = 2.021 SD*		
Station D10	t = 0.000 df = 22 t(.05) = 2.074 NSD	t = 1.934 df = 22 t(.05) = 2.074 NSD	
Station D14	t = 0.299 df = 22 t(.05) = 2.074 NSD	t = 2.152 df = 22 t(.05) = 2.074 SD	
Station D22	t = 0.412 df = 22 t(.05) = 2.074 NSD	t = 1.582 df = 22 t(.05) = 2.074 NSD	t = 0.510 df = 22 t(.05) = 2.306 NSD

TABLE 7c - Summary of t-test between geographically distinct analysis of variance groupings within the June survey for fecal coliform (FC)/100 ml.

Station	23
25	t = 0.681 df = 8 t(.05) = 2.306 NSD

TABLE 7d - Summary of t-test between geographically distinct analysis of variance groupings within the July survey for fecal streptococcus (Enterococcus) (FS)/100 ml.

Stations	D5	D10	D14	D22
D10	t = 0.000 df = 8 t(.05) = 2.306 NSD	t = 0.999 df = 8 t(.05) = 2.306 NSD		
D14	t = 0.999 df = 8 t(.05) = 2.306 NSD	t = 0.999 df = 8 t(.05) = 2.306 NSD		
D22	t = 2.137 df = 8 t(.05) = 2.306 NSD	t = 0.137 df = 8 t(.05) = 2.306 NSD	t = 3.161 df = 8 t(.05) = 2.306 SD	
D31	t = 0.894 df = 8 t(.05) = 2.306 NSD	t = 0.894 df = 8 t(.05) = 2.306 NSD	t = 1.500 df = 8 t(.05) = 2.306 NSD	t = 0.783 df = 8 t(.05) = 2.306 NSD

TABLE 8a - Summary of Tests of Significance Between Analysis of Variance Groups PARAMETER: Total Coliform (TC)/100 ml.

JUNE SURVEY

July Survey: Group or Station	A	D5	D10	D14	D22	D31
A	t = 7.499 df = 259 t(.05) = 1.960 SD**	t = 4.929 df = 117 t(.05) = 1.960 SD**				
B	t = 1.524 df = 164 t(.05) = 1.960 NSD					t = 1.950 df = 22 t(.05) = 2.074 NSD
C	t = 2.087 df = 164 t(.05) = 1.960 SD					
D10			t = 0.952 df = 7 t(.05) = 2.365 NSD			
D14				t = 1.238 df = 8 t(.05) = 2.306 NSD		
D22					t = 1.158 df = 8 t(.05 = 2.306 NSD	

TABLE 8b - JUNE SURVEY
PARAMETER: Total Coliform (TC)/100 ml.

Sept. Survey: Group or Station	A	D5	D10	D14	D22	28	D31
A	t = 5.160 df = 304 t(.05) = 1.960 SD**	t = 1.467 df = 162 t(.05) = 1.960 NSD	t = 0.715 df = 161 t(.05) = 1.960 NSD	t = 1.467 df = 162 t(.05) = 1.960 NSD	t = 2.825 df = 162 t(.05) = 1.960 SD*	t = 0.619 df = 162 t(.05) = 1.960 NSD	t = 1.467 df = 162 t(.05) = 1.960 NSD

TABLE 8c - Summary of Tests of Significance Between Analysis of Variance Groups
PARAMETER: Total Coliform (TC)/100 ml.

JUNE SURVEY

	Group or Station	A	B	C	D10	D14	D22
Sept. Survey	A	t = 13.164 df = 271 t(.05) = 1.960 SD*	t = 0.970 df = 176 t(.05) = 1.960 NSD	t = 4.897 df = 176 t(.05) = 1.960 SD**	t = 0.517 df = 1.62 t(.05) = 1.960 NSD	t = 0.169 df = 172 t(.05) = 1.960 NSD	t = 0.962 df = 162 t(.05) = 1.960 NSD

TABLE 8d - PARAMETER: Fecal Coliform (FC)/100 ml.

JUNE SURVEY

	Group or Station	A	23	25
July Survey	A	t = 6.780 df = 345 t(.05) = 1.960 SD**	t = 1.493 df = 181 t(.05) = 1.960 NSD	t = 0.289 df = 181 t(.05) = 1.960
Sept. Survey	A	t = 1.039 df = 327 t(.05) = 1.960 NSD	t = 9.449 df = 163 t(.05) = 1.960 SD**	t = 5.808 df = 163 t(.05) = 1.960 SD**

8e - PARAMETER: Fecal Coliform (FC)/100 ml

JULY SURVEY

	Group	A
Sept. Survey	A	t = 7.560 df = 336 t(.05) = 1.960 SD**

TABLE 8f - Summary of Tests of Significance Between Analysis of Variance Groups
PARAMETER: Fecal Streptococcus (Enterococcus) (FS)/100 ml.

JUNE SURVEY

Sept. Survey: Group or Station	A	B
A	t = 18.289 df = 317 t(.05) = 1.960 SD**	t = 3.066 df = 156 t(.05) = 1.960 SD*
1	t = 8.918 df = 172 t(.05) = 1.960 SD**	
D5	t = 0.411 df = 172 t(.05) = 1.960 NSD	
D10	t = 0.410 df = 172 t(.05) = 1.960 NSD	
D14	t = 0.788 df = 172 t(.05) = 1.960 NSD	
D22	t = 1.091 df = 172 t(.05) = 1.960 NSD	
D31	t = 0.340 df = 172 t(.05) = 1.960 NSD	

TABLE 8g - Summary of Tests of Significance Between Analysis of Variance Groups
PARAMETER: Fecal Streptococcus (Enterococcus) (FS)/100 ml.

Sept. Survey: Group	A	B
A	t = 1.411 dfq = 327 t(.05) = 1.960 NSD	t = 12.524 df = 166 t(.05) = 1.960 SD**

TABLE 8h - PARAMETER: Fecal Streptococcus (Enterococcus)(FS)/100 ml.

JULY SURVEY

Sept. Survey	Group or Station	A	1	D5	D10	D14	D22	D31
	A	t = 21.843 df = 308 t(.05) = 1.960 SD**	t = 12.681 df = 163 t(.05) = 1.960 SD**	t = 0.153 df = 163 t(.05) = 1.960 NSD	t = 0.153 df = 163 t(.05) = 1.960 NSD	t = 0.684 df = 163 t(.05) = 1.960 NSD	t = 1.951 df = 163 t(.05) = 1.960 NSD	t = 0.895 df = 163 t(.05) = 1.960 NSD

GLOSSARY OF TERMS

ALKALINITY :The alkalinity of a water sample is a measure of its capacity to neutralize acids. This capacity is due to carbonate, bicarbonate and hydroxide ions and is arbitrarily expressed as if all of the neutralizing capacity was due to calcium carbonate alone.

ANOXIC :Refers to conditions when no oxygen is present.

BACKGROUND COLONIES :Background colonies are other lake water bacteria capable of growing on the total coliform plate, in spite of the inherent restrictive conditions.

CHLORIDE :Chloride is simply a measure of the chloride ion concentration and is not a measure of chlorination.

CHLOROPHYLL a :A green pigment in plants.

CONDUCTIVITY :Conductivity is a measure of the waters ability to conduct an electric current and is due to the presence of dissolved salts.

DIATOMS :Unicellular plants found on all continents and in all types of water where light and nutrients are sufficient to support photosynthesis. They are comprised of two siliceous frustules (cell walls) which have an outer valve (epitheca) fitting over the inner valve (hypotheca) like the lid on a box. The siliceous deposits comprising the frustules vary in regular patterns according to the individual species.

EPILIMNION :Is the thermally uniform layer of a lake lying above the thermocline. Figure I.

EUPHOTIC ZONE :The lighted region that extends vertically from the water surface to the level at which photosynthesis fails to occur due to insufficient light penetration.

EUTROPHIC :Waters containing advanced nutrient enrichment and characterized by a high rate of organic production.

EUTROPHICATION :The process of becoming increasingly enriched in nutrients. It refers to the entire complex of changes which accompanies increasing nutrient enrichment. The result is the increased production of dense biological growths such as algae and aquatic weeds which generally degrade water quality and render the lake unsuitable for many recreational activities.

FECAL COLIFORMS (FC) :Fecal coliforms are bacteria associated with recent fecal pollution from man and animals.

FECAL STREPTOCOCCUS (FS) :Fecal streptococcus are bacteria associated with fecal pollution from animals and to a lesser extent man.

HARDNESS :Hardness of water is a measure of the total concentration of calcium and magnesium ions expressed as if all of the ions were calcium carbonate.

HYPOLIMNION :The uniformly cold and deep layer of a lake lying below the thermocline, when the lake is thermally stratified. Diagram #1

KJELDAHL NITROGEN :Sum of nitrogen present in the ammonia and organic forms (it does not include nitrite or nitrate).

MESOTROPHIC :Waters characterized by a moderate nutrient supply and organic production (i.e. midway between eutrophic and oligotrophic).

METALIMNION :See thermocline.

OLIGOTROPHIC :Waters containing a small nutrient supply and consequently characterized by a low rate of organic production.

pH :Is the measure of the hydrogen ion concentration expressed as the negative logarithm of the molar concentration.

PHOSPHORUS (TOTAL) :Sum of all forms of phosphorus present in the sample.

SECCHI DISC :A circular metal plate, 20 centimeters in diameter, the upper surface of which is divided into four equal quadrants. Two quadrants directly opposite each other are painted black and the intervening ones white. The secchi disc is used to estimate the turbidity of the lake water.

THERMAL STRATIFICATION :During the spring, vertical temperatures in a lake are homogeneous from top to bottom. As summer advances, the surface waters become warmer and less dense than the underlying cooler waters. A strong thermal gradient (thermocline) occurs giving rise to three distinct water layers. The variation in density between layers retards mixing by wind action and water currents. See Diagram #1.

THERMOCLINE (METALIMNION) :The layer of water located between the epilimnion and hypolimnion in which the temperature exhibits a decline equal to or exceeding $1^{o}C$ increase per meter.

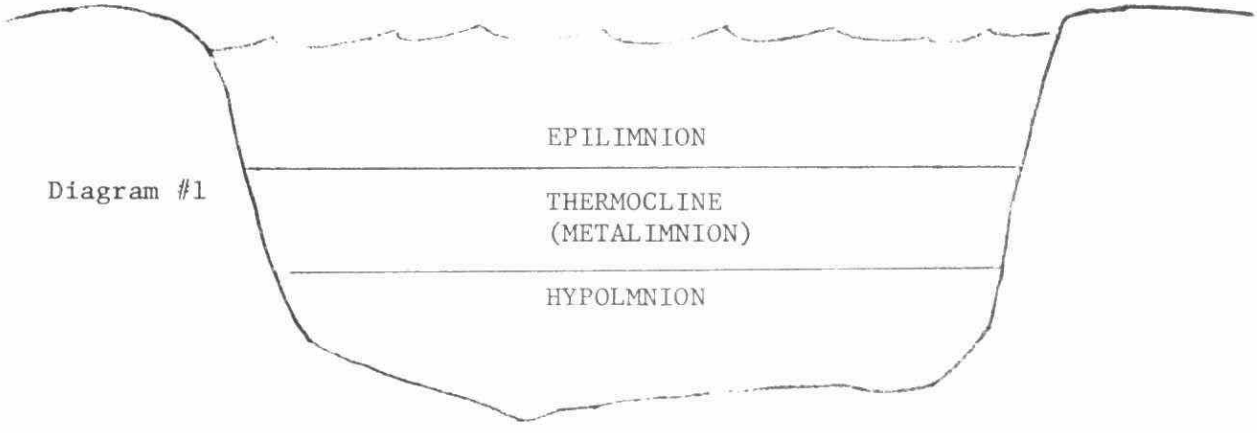


Diagram #1

TOTAL COLIFORMS (TC) :Total coliforms are bacteria commonly associated with fecal pollution but may also be present naturally in the environment.

TROPHIC STATUS :Depending upon the degree of nutrient enrichment and resulting biological productivity, lakes are classified into three integrading types:

TROPHIC STATUS (continued)

oligotrophic, mesotrophic and eutrophic. If the supply of nutrients to an oligotrophic lake is progressively increased, the lake will become more mesotrophic in character and with continued enrichment it will become eutrophic.

BIBLIOGRAPHY

BAKER, A.L., BROOK, A.J. and Klemer, A.R. 1969 Some photosynthetic characteristics of a naturally occurring population of Oscillatoria agardhii Gomont. Limnol. Oceanogr. 14(3):327-333

BENNETT, E.A. Taken from the Great Lakes as an Environment. Edited by D.V. Anderson, Great Lakes Institute Report PR 39, University of Toronto, October 1969

_____ Investigations of Daily Variations in Chemical Bacteriological and Biological Parameters at two Lake Ontario locations near Toronto. Proc. 12th. Conf. Great Lakes Res. 1969. 21-38 Internat. Association. Great Lakes Res.

BROWN D.J. 1972 Chlorophyl a - Secchi disc relationship in Ontario Recreational Lakes (In Preparation).

BURGER, A. Statistical Bacterial Data Summarization and Interpretation Internal OWRC Report (Unpublished).

EBERLY, W.R. 1959 The metalimnetic oxygen maximum in Meyer's Lake. Invest. Indiana Lakes and Streams 5(1): 1-46.

_____ 1963 Oxygen production in some Northern Indiana Lakes. Proc. Industrial Waste Conference, Purdue University 17:733-747.

_____ 1964 Further studies on the metalimnetic oxygen maximum with special reference to its occurrence throughout the world. Invest. Indiana Lakes and Streams 6:103-139.

EDMONDSON, W.R. 1970 Phosphorus, Nitrogen and Algae in Lake Washington after Diversion of Sewage. Science 169 No. 3946 : 690-691.

GELDREICH, E.E., BEST, L.C., KENNER, B.A., VAN DORSEL, D.J. The Bacteriological Aspects of Storm-water Pollution J. WPCF Vol. 40 No. II, Part I 1968 pp. 1861-1872.

Guidelines and Criteria for Water Quality Management in Ontario, OWRC, June 1970.

International Lake Erie Water Pollution Board and the International Lake Ontario-St. Lawrence River Water Pollution Board (1969) report to the International Joint Commission on the Pollution of Lake Erie, Lake Ontario and the International Section of the St. Lawrence River, Vol. 1 Summary.

RICHARDS, F.A. and THOMPSON, T.G. 1952. The estimation and characterization of plankton populations by pigment analysis II. The spectrophotometric method for the estimation of plankton pigments. J. Marine Res., 11:156.

ROHLF, F.J. AND SOKAL, R.R., 1969. Statistical Tables, W.H. Freeman and Company, San Francisco.

SOKAL, R.R. and Rohlf, F.J., 1969, Biometry, the principals and practices of statistics in biological research, W.H. Freeman and Company, San Francisco.

Standard Methods for the Examination of Water and Wastewater, 13th. Edition, 1971. APHA, AWWA, WPCF.

STOCKNER, J.G. 1971. Preliminary characterization of lakes in the Experimental Lakes Area, Northwestern Ontario, using diatom occurrences in sediments. J. Fish, Res. Ed. Canada 28:265-275.

WETZEL, R.G. 1966. Variations in productivity of Goose and hypereutrophic Cylvan lakes, Indiana. Invest. Indiana Lakes and Streams V7(5): 147-184.